A benthic survey of sandbank features in the Irish Sea

A biological survey of the Bray, Money-weights and Lucifer Banks

July 2010

A Report to the Department of the Environment, Heritage & Local Government

Aquatic Services Unit

Table of Contents

1 Introduction

Aquatic Services Unit (ASU) was contracted by the Department of the Environment, Heritage and Local Government (DEHLG) to undertake a subtidal benthic survey at three separate sandbanks in the Irish Sea; Bray Bank, Money-Weights Bank & Lucifer Bank (Figure 1).

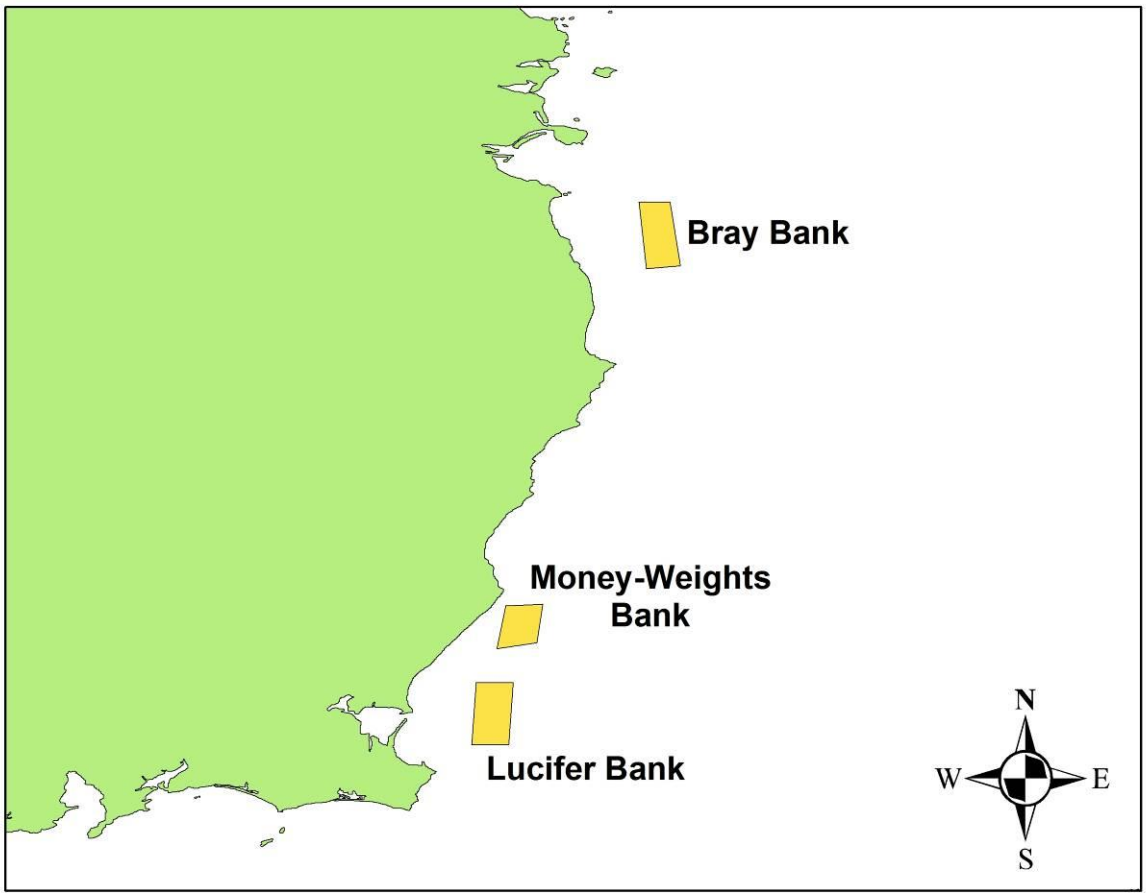

Figure 1: Locations of each of the sandbanks along the eastern Irish seaboard.

2 Materials & Methods

Sampling locations were selected to maximise the depth profile across each sandbank. In total, 22 locations were sampled across the three sandbanks. A total of 11 sampling stations were selected for Bray Bank, 5 sampling stations were selected for the Money-Weights Bank and 6 sampling stations were selected for the Lucifer Bank. All sampling locations were chosen in conjunction with the DEHLG.

2.1 Pre-Field Assessment Checks

Prior to all field campaigns, pre-fieldwork checks were undertaken to allow for a detailed visual inspection of all equipment. Batteries were charged and all electronic equipment was tested

prior to departure. Predetermined sampling positions which had been identified were pre-loaded into the vessels on-board differential GPS.

Sampling containers were cleaned and labelled prior to departure. Each survey area was uniquely coded and sampling positions within each area were then assigned a numeric code unique to each station. In addition, waterproof labels were written prior to field sampling. Two duplicate labels were written for each sampling position and placed in each pre-labelled sampling container.

2.2 Field Sampling

Fieldwork was carried out aboard the MV Island Flyer on the 24th April 2010 for the Lucifer and Money-Weights Banks and 28th May 2010 for the Bray Bank. All sampling stations were positioned using the vessels on-board GPS. A complete list of stations sampled and the stations are displayed on a map (Figure 2) and are presented in Table I.

	Latitude	Longitude		Easting	Northing
Bray 1	706600	5902783	Money-Weights 1	692659	5822972
Bray 2	706188	5901023	Money-Weights 2	692483	5820990
Bray 3	706830	5900980	Money-Weights 3	692560	5819684
Bray 4	706307	5899632	Money-Weights 4	692327	5818535
Bray 5	705794	5898743	Money-Weights 5	692647	5816799
Bray 6	706274	5897837	Lucifer 1	689271	5806405
Bray 7	706374	5897676	Lucifer 2	690467	5804154
Bray 8	706552	5896124	Lucifer 3	688171	5802764
Bray 9	706396	5894850	Lucifer 4	688414	5798993
Bray 10	706923	5894495	Lucifer 5	689372	5796492
Bray 11	706764	5896545	Lucifer6	689338	5797490

Table I: Sampling positions of all subtidal sampling positions in the Irish Sea. Sampling positions are presented in UTM (Zone 29N).

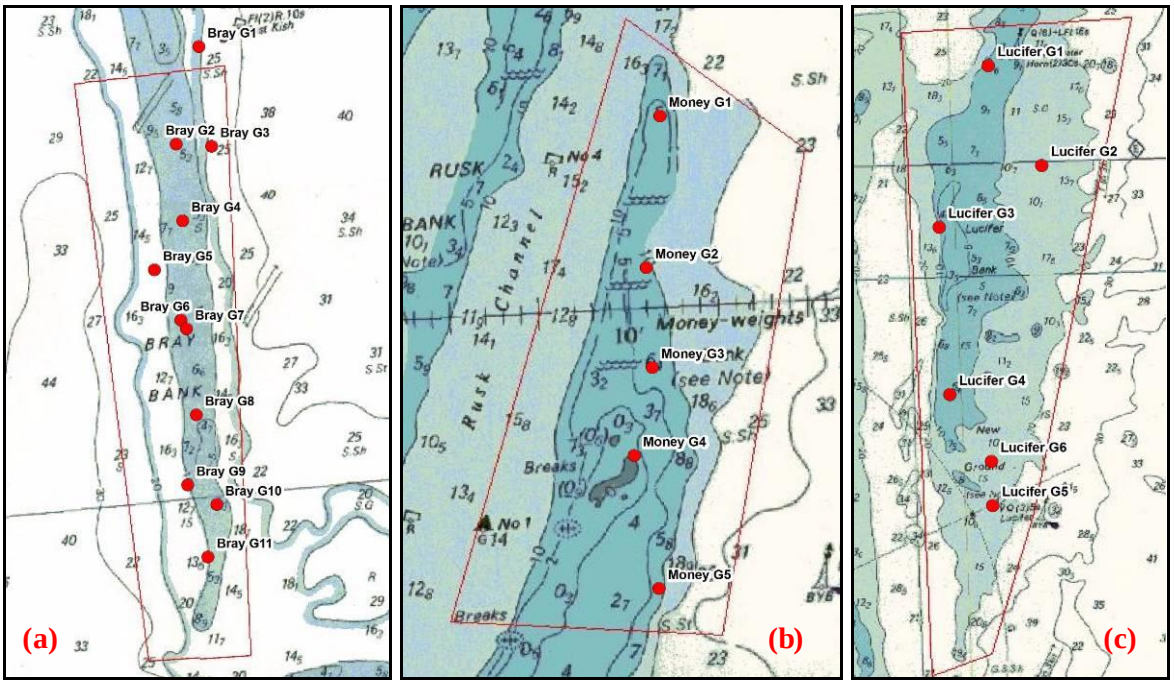

Figure 2: Map of grab sampling locations in each of the sandbanks in the Irish Sea. (a) – Bray Bank; (b) Money-Weights Bank; (c) Lucifer Bank

At each sampling location

- A single 0.1m² Van-Veen Grab was deployed at 22 locations across the three survey areas. On retrieval, samples were checked and depth measurements of the sediment were taken in-situ in the grab to ensure sufficient sediment was collected as outlined in the Marine Monitoring Handbook (JNCC, 2001).
- Photographs were recorded of the sediment *in-situ* in the grab. The sediment was transferred to a large container and a second photograph recorded of the sediment.
- A small sub-sample (~100g) was removed for particle size and loss on ignition analysis and transferred to a labelled container.
- Samples for macrofaunal analysis were gently sieved through a 1.0mm mesh sieve and fixed in 10% buffered formalin. Samples were transferred to labelled containers and fixed using 10% buffered formalin.
- Ancillary sampling details were recorded for each site
    - Visual sediment assessment (broad sediment type)
    - Presence of anoxic layer and odour
    - Sample volume
    - Details on equipment used and sieve mesh size

2.3 Laboratory Analyses

2.3.1 Particle Size Analysis

On arrival back to the laboratory the sediment samples were either transferred to a 4ºC cold room or the drying process was started immediately. All particle size analyses were initiated on all samples within 3 days of collection.

To start the drying process, the collected sediments were transferred to aluminium trays, homogenised by hand and dried in an oven at 100 ºC for 24 hours. The oven dried samples were then ready for grain size analyses following the methodology below as described by Holme & McIntyre (1984).

- Approximately 25g of dried sediment was weighed out and placed in a labelled 1L glass beaker to which 100 ml of a 6 percent hydrogen peroxide solution was then added. This was allowed to stand overnight in a fume hood.
- The beaker was then placed on a hot plate and heated gently. Small quantities of hydrogen peroxide were added to the beaker until there was no further reaction. This peroxide treatment removes any organic material from the sediment which can interfere with grain size determination.
- The beaker was then emptied of sediment and rinsed into a. 63µm sieve. This was then washed with distilled water to remove any residual hydrogen peroxide. The sample retained on the sieve was then carefully washed back into the glass beaker up to a volume of approximately 250ml of distilled water.
- 10ml of sodium hexametaphosphate solution was then added to the beaker and this solution was stirred for ten minutes and then allowed to stand overnight. This treatment helps to dissociate the clay particles from one another.
- The beaker with the sediment and sodium hexametaphosphate solution was then washed and rinsed into a 63µm sieve. The retained sampled was then carefully washed from the sieve into a labelled aluminium tray and placed in an oven for drying at 100ºC for 24 hours.
- When dry this sediment was sieved through a series of graduated sieves ranging from 4 mm down to 63µm for 10 minutes using an automated column shaker. The fraction of sediment retained in each of the different sized sieves was weighed and recorded.
- The silt/clay fraction was determined by subtracting all weighed fractions from the initial starting weight of sediment as the less than 63µm fraction was lost during the various washing stages.

2.3.2 Loss on Ignition Analysis

On arrival back to the laboratory the sediment samples were either transferred to a 4ºC cold room or the drying process was started immediately. Loss on Ignition (LOI) is a proxy measurement of the amount or organic material in sediment. LOI analysis was initiated on all samples within 3 days of collection. Analysis was carried out following the methods described below.

- Initially, the collected sediments were transferred to aluminium trays, homogenised by hand and then dried in an oven at 100ºC for 24 hours.
- A sample of dried sediment was then placed in a mortar and pestle and ground down to a fine powder.
- 1g of this ground sediment was weighed into a pre-weighed crucible and placed in a muffle furnace at 450ºC for a period of 6 hours.
- The sediment samples were then allowed to cool in a desiccator for 1 hour before being weighed again.
- The organic content of the sample was determined by expressing as a percentage the weight of the sediment after ignition over the initial weight of the sediment.

2.3.3 Faunal Sorting

All samples were processed and fixed within 24 hours of collection. All samples were gently puddled through a 1mm mesh sieve on-board the vessel. Samples were back-washed into labelled sampling containers and fixed in 10% buffered saline formalin solution. No dye was added to the formalin solution on recommendation from the taxonomists. Two waterproof labels were added to each sample container.

Samples were sorted by eye, using binocular microscopes. Conspicuous fauna was placed in an illuminated white tray and sorted first to remove large specimens. Following the removal of large faunal specimens, samples were placed into Petri dishes and sorted using binocular microscopes.

All faunal samples were stored in 70% ethanol, separated according to taxonomic grouping and sent by courier to the appropriate faunal taxonomist.

2.3.4 Faunal Identification

Fauna was sent to the following individuals for identification

Molluscs
[redacted]

Polychaetes and Oligochaetes
[redacted], Identichaet

Crustaceans & Others
[redacted], Oxford University Museum of Natural History.

2.4 Data Analysis

2.4.1 Faunal Analysis

A number of univariate and multivariate analyses were performed on the datasets to ascertain the presence of discrete and unique communities that would not be readily identified by simply examining the raw data. The overall aim of these analyses was to characterise the communities present and identify discrete biotope groups. Each site was assigned a biotope using the Habitat Classification Scheme derived by JNCC (Connor *et al.*, 2004).

Univariate analysis on the dataset included the calculation of several defined biological indices (such as diversity, evenness and species richness). A number of diversity indices were calculated which included the Shannon-Wiener Diversity Index [H'] (Pielou, 1977), Pielou's Evenness Index [E] (Pielou, 1977) and Margalef's Species Richness [dmg] (Margalef, 1958). The Shannon-Wiener diversity index allows for a measurement reflecting the distribution of the species number across the number of individuals. It ranges from 0 (low diversity) to 5 (high diversity). Pielou's evenness is a measure on how evenly the individuals are distributed across the number of species. It ranges from 0 (low evenness) to 1 (high evenness). Margalef's species richness is a measure of the number of species present in relation to the number of individuals present. It ranges from 0 (low richness) to 12 (high richness). All diversity indices were calculated using the BIODIV computer programme.

Multivariate analysis of the faunal data was undertaken using the statistical package PRIMER v. 5 (Clarke & Warwick, 2001). All abundance data was fourth root transformed to reduce the importance of highly abundant species. A Bray-Curtis similarity matrix was produced and this similarity matrix was used for the cluster analysis and non-metric Multi Dimensional Scaling (MDS) analysis.

Cluster analysis allows for creation of a 2-dimensional structure (dendogram) based on the similarity of stations to each other, and allows for the identification of discrete groups based on faunal similarities.

Non-metric multidimensional scaling (MDS) was undertaken on the Bray-Curtis similarity matrix to produce an ordination. This MDS ordination was then used to identify groups of samples which have similar faunal assemblages. Each MDS ordination also produces a stress value which allows for a good interpretation of how good the two-dimensional plot represents the multi-dimensional sample relationship. Clarke and Warwick (2001) have provided guidelines on these values and their relationship with the faunal plots. These are outlined below

- Stress Value <0.05: Excellent representation of the data.
- Stress Value <0.10: Good representation of the data. Some fine detail may be misinterpreted.
- Stress Value <0.20: Useful representation of the data. Some detail may be misinterpreted.
- Stress Value >0.20: Data should be viewed with caution. The data may be randomly distributed within the ordination and may not represent the underlying dataset.

2.4.2 Sediment Analysis

Results from the particle size analysis and loss on Ignition, were combined with depth data (relative values) and analysed using Principal Component Analysis (PCA). The dataset was transformed to reduce the influence of outliers on the results. Particle size percentage data was $\log_{10}+1$ transformed, whilst Skewness, Kurtosis and Median values, in addition to loss on ignition data, were square root transformed. All variables were checked for correlations and one of the variables was removed from further analysis if significant correlations (>0.95) were identified. All data analysis was undertaken using the PCA subroutine in Primer v. 5. (Clarke & Warwick, 2001)

3 Results

3.1 Bray Bank

3.1.1 Faunal Results

A full taxonomic list of species identified for the current survey is presented in Table II. Overall, abundances and diversity is very low across the Bray Bank. A total of 34 individuals from 7 taxa were identified across all 11 sites. These included only 3 crustaceans and 4 Polychaetes.

	Bray1	Bray2	Bray3	Bray4	Bray5	Bray6	Bray7	Bray8	Bray9	Bray10	Bray11
Bathyporeia guilliamsonina	0	0	0	4	1	0	2	0	1	0	0
Urothoe marina	1	0	0	0	0	0	0	0	0	0	0
Eurydice spinigera	0	0	0	0	0	0	0	0	0	0	1
Nephtys cirrosa	2	2	3	0	2	0	0	0	1	0	1
Nephtys longesetosa	0	0	0	0	1	0	1	1	0	0	0
Spio armata	0	1	0	0	1	0	0	0	0	0	0
Magelona johnstoni	0	0	8	0	0	0	0	0	0	0	0

Table II: Species/Abundance matrix table for all 11 stations identified along Bray Bank in May 2010.

These low abundances are reflected in the diversity indices identified across the site along the Bray Bank (Table III).

	No. Species	No. Individuals	Species Richness	Diversity	Evenness
Bray1	2	3	0.91	0.637	0.918
Bray2	2	3	0.91	0.637	0.918
Bray3	2	11	0.417	0.586	0.845
Bray4	1	4	0	0	n/r
Bray5	4	5	1.86	1.33	0.961
Bray6	0	0	n/r	n/r	n/r
Bray7	2	3	0.91	0.637	0.918
Bray8	1	1	n/r	0	n/r
Bray9	2	2	1.44	0.693	1
Bray10	0	0	n/r	n/r	n/r
Bray11	2	2	1.44	0.693	1

Table III: Diversity indices for all 11 stations sampled along Bray Bank in May 2010.

Results from multivariate analysis identify the presence of 2 discrete groups across Bray Bank, with Group I consisting of 2 sub-groups (Figures 4 & 5). The groupings identified are based on

>40% similarity as identified by the red line present in the group average sorting dendogram presented in Fig. 4.

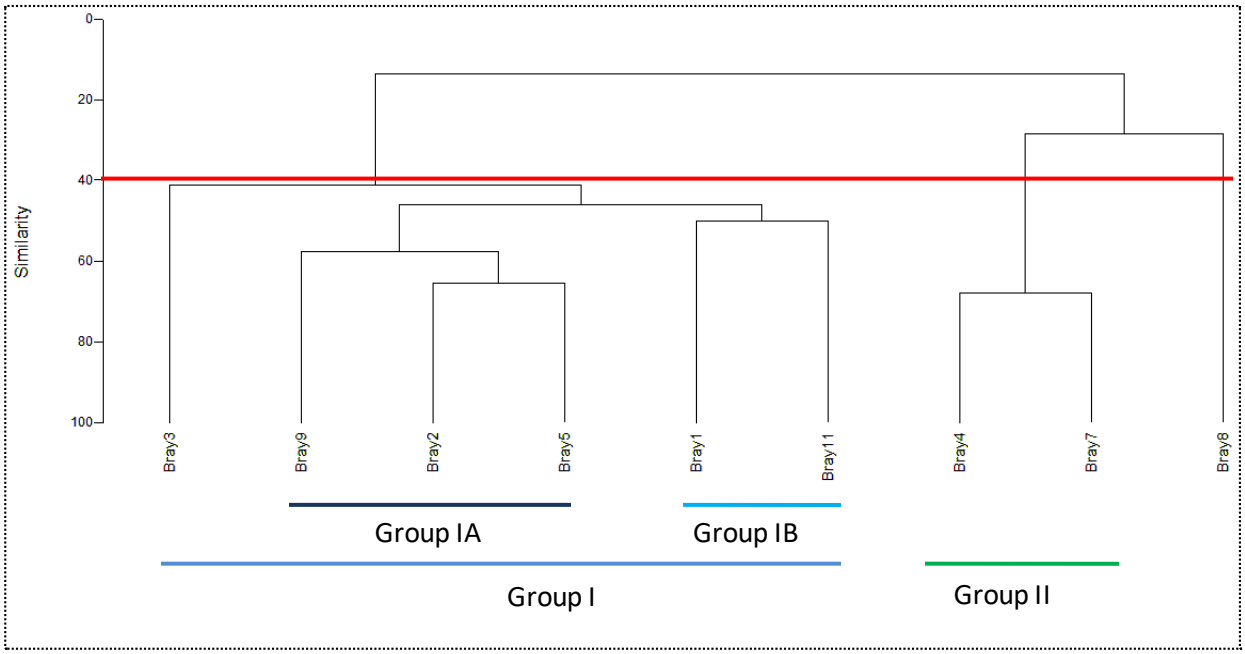

Figure 4: Group average sorting dendogram on all 11 stations sampled from Bray Bank in May 2010.

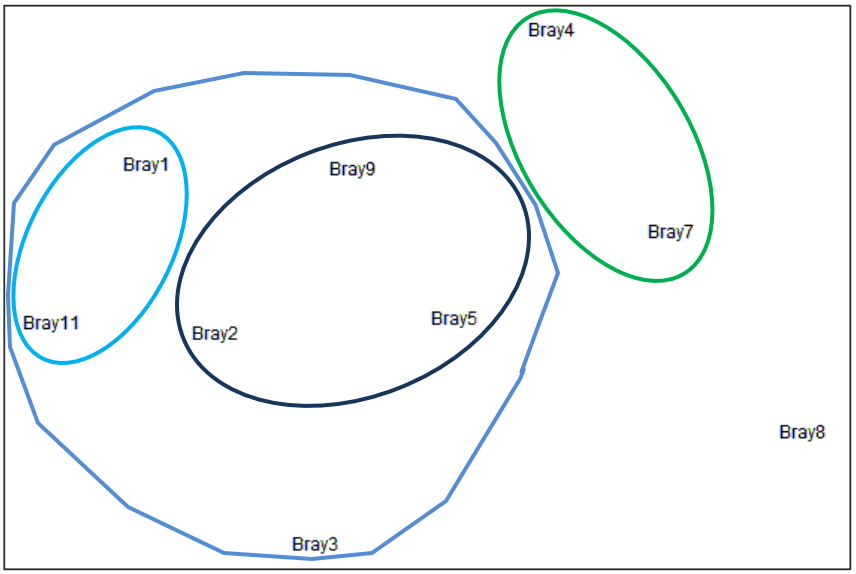

Figure 5: MDS plot of all 11 stations sampled from Bray Bank in May 2010. (Stress = 0.08)

These groupings were also preserved in the MDS ordination (Fig. 5). The stress value of the MDS is 0.08 indicating a good representation of the data, although it should be noted that abundances are low across the dataset.

The groups identified in the multivariate analysis are labelled

- Group Ia – Bray 2, Bray 5 & Bray 9
- Group Ib – Bray 1 & Bray 11
- Group II – Bray 4 & Bray 7

Group I separated from all other groups at 13.5% similarity level. Bray 8 (the outlier sample) separated from Group II at the 28.5% similarity level. Within Group I, Bray 3 separated from Groups Ia and Ib at the 41.3% similarity level. Overall, Group I had a 47.6% similarity (Group Ia had a 60.4% similarity and Group Ib had a 50.3% similarity) and Group II had a 67.9% similarity.

3.1.2 Sediment Results

Results from Particle Size Analysis on the sediments from the Bray Bank are presented in Table IV.

	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt/ Clay	Classification
Bray 1	0.00%	0.00%	1.29%	68.29%	27.86%	0.19%	2.37%	Moderately Well Sorted Medium Sand
Bray 2	2.95%	1.85%	6.84%	32.54%	52.47%	1.00%	2.35%	Slightly Very Fine Gravelly Fine Sand
Bray 3	0.00%	0.38%	1.03%	10.84%	81.37%	3.82%	2.56%	Well Sorted Fine Sand
Bray 4	0.00%	0.00%	0.32%	9.81%	88.62%	0.36%	0.90%	Very Well Sorted Fine Sand
Bray 5	2.83%	3.17%	6.63%	35.49%	50.52%	0.44%	0.91%	Slightly Very Fine Gravelly Fine Sand
Bray 6	0.00%	0.15%	1.08%	23.61%	72.07%	0.22%	2.87%	Well Sorted Fine Sand
Bray 7	0.38%	0.26%	0.21%	16.92%	80.87%	0.47%	0.89%	Slightly Very Fine Gravelly Fine Sand
Bray 8	0.00%	0.30%	4.33%	52.77%	40.88%	0.11%	1.60%	Well Sorted Medium Sand
Bray 9	0.00%	0.00%	6.13%	86.70%	5.48%	0.00%	1.69%	Very Well Sorted Medium Sand
Bray 10	0.00%	0.00%	17.26%	79.01%	1.98%	0.03%	1.72%	Very Well Sorted Medium Sand
Bray 11	0.00%	0.00%	1.91%	84.50%	11.54%	0.06%	1.99%	Well Sorted Medium Sand

Table IV: Particle Size Analysis results for sediments taken along the Bray Bank in May 2010.

The sediment results indicate the sediment present across the Bray Banks consists of medium to fine sands, with very little gravel present from the sample stations. Medium sands dominated 5 stations (Bray 1, Bray 8, Bray 9, Bray 10 & Bray 11) with fine sands dominating the remaining 6 stations (Bray 2, Bray 3, Bray 4, Bray 5, Bray 6 & Bray 7). Bray 2 & Bray 5 returned the highest gravel and very coarse sand percentages across the 11 stations with 2.95% & 2.83% fine gravel and 1.85% & 3.17% very coarse sand respectively. Bray 10 returned the highest coarse sand percentage (17.26%), Bray 9 returned the highest percentage of medium sand (86.7%), Bray 4 returned the highest percentage of fine sand (88.62%) and Bray 3 returning the highest

percentage of very fine sands (3.82%). Silt/Clay levels were low across the survey area, as expected, with values ranging from 0.89% at Bray 7 to 2.87% at Bray 6. The distribution of the sediment across the Bray Bank is presented in Figure 6.

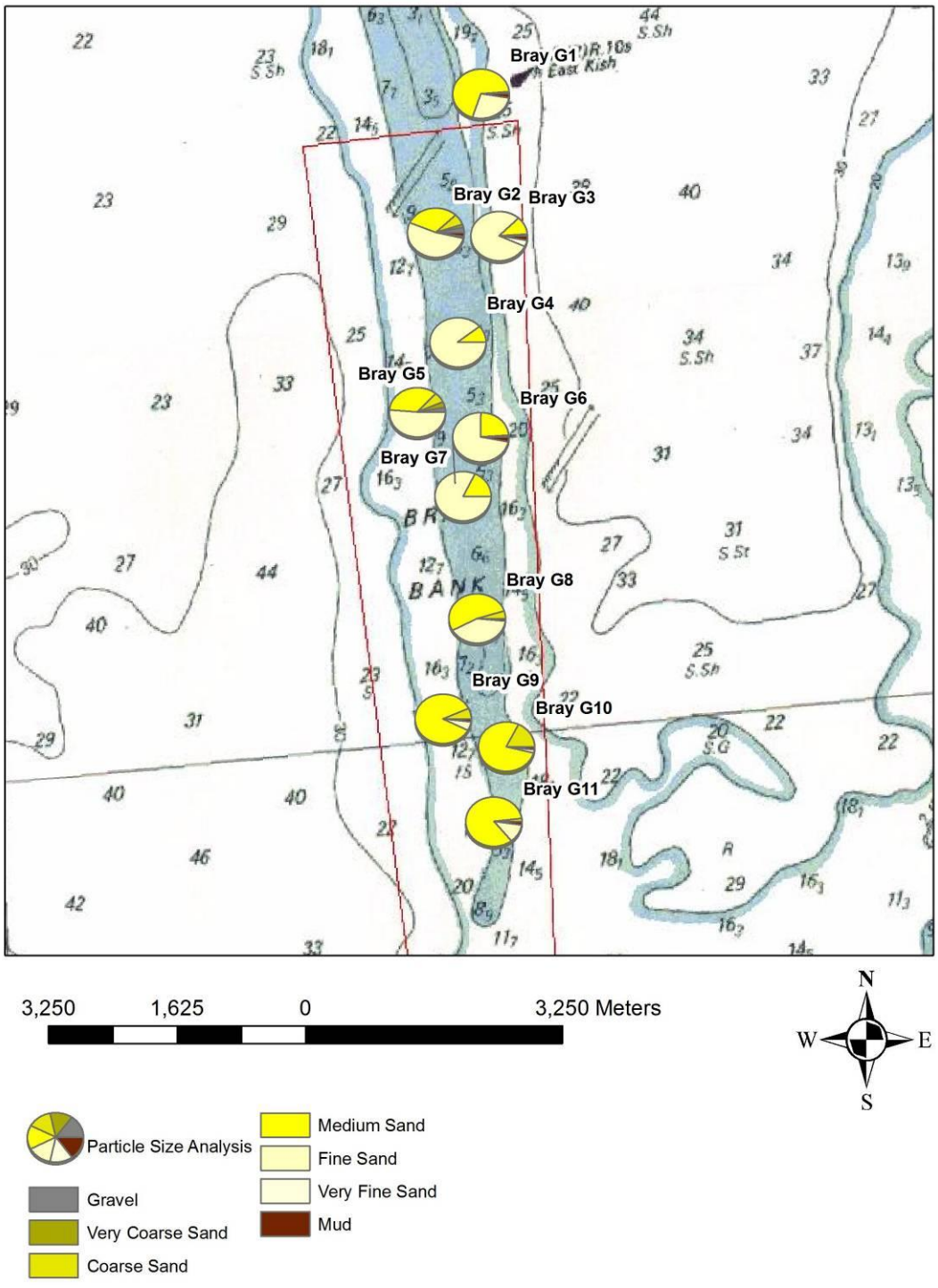

Figure 6: Sediment distribution across Bray Bank in May 2010. [Not to be used for Navigation © Crown Copyright and/or database rights. Reproduced under licence no. 14483 by permission of the Controller of Her Majesty's Stationery Office and the UK Hydrographic Office (www.ukho.gov.uk).]

Results from LOI analysis indicate very low organic values across the site (Table V). LOI values across the bank ranged from 0.499% at Bray 6 to 0.838% at Bray 3.

Station	Organic Carbon (% LOI)
Bray 1	0.596
Bray 2	0.572
Bray 3	0.838
Bray 4	0.565
Bray 5	0.594
Bray 6	0.499
Bray 7	0.501
Bray 8	0.564
Bray 9	0.625
Bray 10	0.694
Bray 11	0.619

Table V: Loss on Ignition results for sediments taken at the Bray Bank in May 2010.

Figure 7 shows the PCA ordination of the sediment data analysed from the Bray Bank. This two-dimensional ordination accounts for 59.6% of the overall variation. PC1 accounts for 34.4% of the variation and PC2 accounts for 25.2% of the variation. A clear difference between medium and fine sand sites is evident in the data, with all medium sand sites present in a tight group highlighted by a black circle in Figure 7. There is a large degree of separation between the fine sand sites. Bray 2 and Bray 5 contain increased levels of very fine gravel compared to all other fine sand sites. Bray 3 had increased very fine sands and increased LOI compared to all other sites.

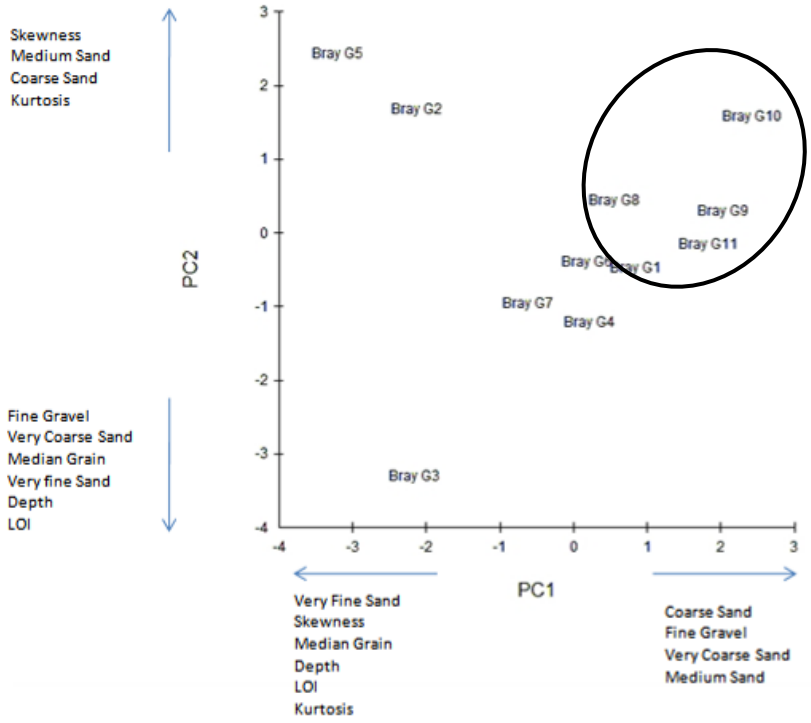

Figure 7: Two-dimensional PCA ordination of environmental data sampled at the Bray Bank in May 2010.

3.1.3 Biotope Assessment

Multivariate analysis identified the presence of two distinct groups, with two sub-groups within the Bray Bank dataset. Group I contained 7 species; crustaceans *Bathyporeia guilliamsonina*. *Urothoe marina* & *Eurydice spinigera*, and the polychaetes *Nephtys cirrosa*, *Nephtys longesetosa*, *Spio armata* & *Magelona johnstoni*. The subgroups(Ia and Ib) within Group I are only separated by the presence of the polychaete *Spio armata*. This group has been classified as the biotope SS.SSa.IFiSa.IMoSa – Infralittoral mobile clean sand with sparse fauna.

Group II contained only 2 species, the crustacean *Bathyporeia guillimasoniana* and the polychaete *Nephtys longesetosa*. Abundances of *B. guillimasoniana* were increased compared to those identified in Group I. This group has also been identified as the biotope SS.SSa.IFiSa.IMoSa – Infralittoral mobile clean sand with sparse fauna.

This biotope is typical of medium to fine sandy sediment in shallow waters, such as those identified along the Bray Bank. These sediments contain very little infauna due to the mobility of the sediments, with only opportunistic species likely to occur in low numbers such as *Bathyporeia guillimasoniana*, *Eurydice pulchra* and *Nephtys cirrosa*.

3.2 Money-Weights & Lucifer Banks

3.2.1 Faunal Results

The Money-Weights and Lucifer Banks were analysed together due to the close proximity of the banks and the limited number of samples taken on each bank. Six samples were collected from the Lucifer Bank and five samples were collected from the Money-Weights Bank.

A full taxonomic list of species identified for both banks is presented in Table II. Overall, abundances and diversity is very low across both banks. A total of 52 individuals from 10 taxa were identified across all 11 sites. These included 1 fish *Ammodytes tobianus*, 3 crustaceans *Bathyporeia guillimasoniana*, *Urothoe marina* & *Perioculodes longimanus* and 6 polychaetes *Glycera tridactyla*, *Nephtys cirrosa*, *Nephtys longosetosa*, *Schistomeringos* indet., *Spio armata* & *Ophelia borealis*.

	Money 1	Money 2	Money 3	Money 4	Money 5	Lucifer 1	Lucifer 2	Lucifer 3	Lucifer 4	Lucifer 5	Lucifer 6
Ammodytes tobianus	1	0	0	0	0	0	0	0	0	0	0
Bathyporeia guillimasoniana	0	3	6	5	11	1	1	0	0	0	0
Urothoe marina	3	0	0	0	0	0	0	1	0	0	0
Perioculodes longimanus	0	0	0	0	0	0	0	0	0	0	1
Glycera tridactyla	0	0	2	0	0	0	0	0	0	0	0
Nephtys cirrosa	0	0	1	0	0	1	1	0	1	2	0
Nephtys longosetosa	0	0	0	0	0	0	0	1	0	0	0
Schistomeringos indet.	0	0	0	0	0	0	0	1	0	0	0
Spio armata	0	0	0	0	0	1	0	0	0	0	0
Ophelia borealis	7	0	0	0	0	0	0	1	0	0	0

Table VI: Species/Abundance matrix table for all 11 stations identified along Money-Weights and Lucifer Banks in April 2010.

These low abundances are reflected in the diversity indices identified across the site along the Money-Weights and Lucifer Banks (Table VII).

	No. Species	No. Individuals	Species Richness	Diversity	Evenness
Money 1	3	11	0.834	0.860	0.783
Money 2	1	3	0	0	n/r
Money 3	3	9	0.91	0.849	0.773
Money 4	1	5	0	0	n/r
Money 5	1	11	0	0	n/r
Lucifer 1	3	3	1.82	1.1	1
Lucifer 2	2	2	1.44	0.693	1
Lucifer 3	4	4	2.16	1.39	1
Lucifer 4	1	1	n/r	0	n/r
Lucifer 5	1	2	0	0	n/r
Lucifer 6	1	1	n/r	0	n/r

Table VII: Diversity indices for all 11 stations sampled along the Money-Weights and Lucifer Banks in April 2010.

Results from multivariate analysis identify the presence of 3 discrete groups across both banks (Figures 8 & 9). The groupings identified are based on >40% similarity as identified by the red line present in the group average sorting dendogram presented in Fig. 8.

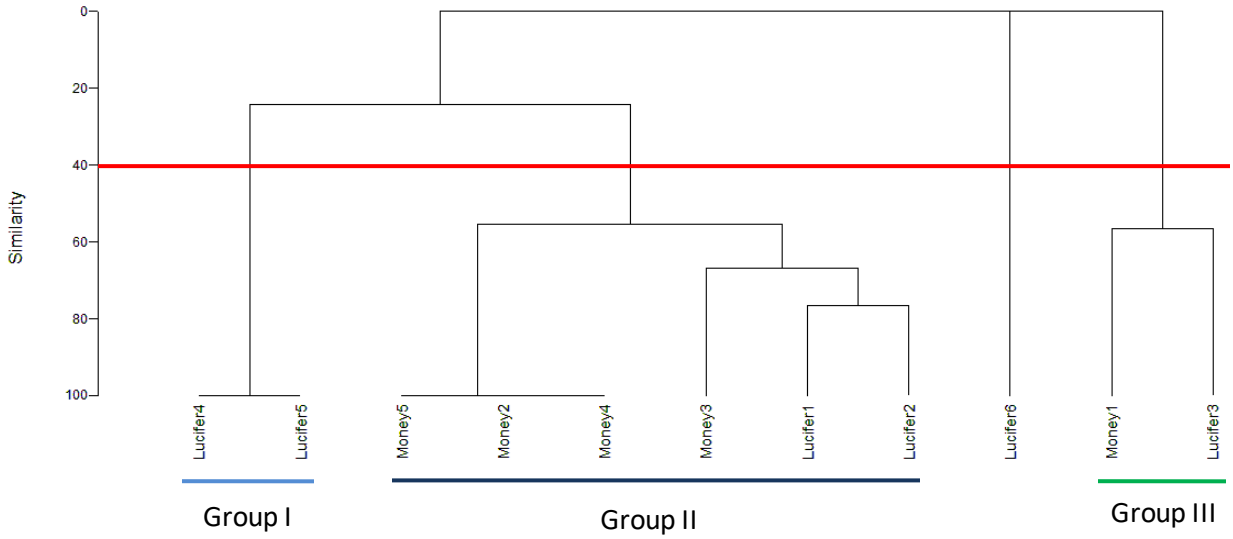

Figure 8: Group average sorting dendogram on all 11 stations sampled from the Money-Weights and Lucifer Banks in April 2010.

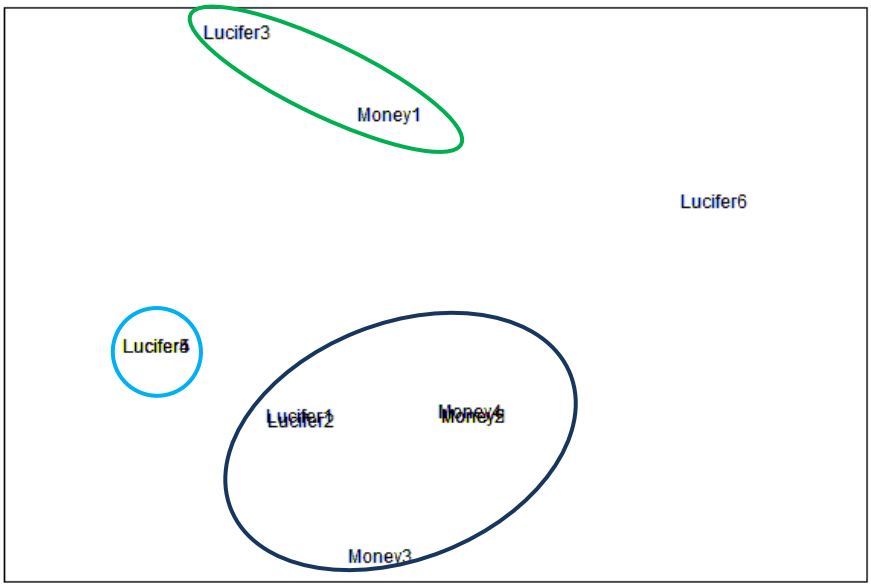

Figure 9: MDS plot of all 11 stations sampled from the Money-Weights and Lucifer Banks in April 2010. (Stress = 0.01)

These groupings were also preserved in the MDS ordination (Fig. 9). The stress value of the MDS is 0.01 indicating an excellent representation of the data, although it should be noted that abundances are low across the dataset.

The groups identified in the multivariate analysis are labelled

- Group I – Lucifer 4 & Lucifer 5
- Group II – Lucifer 1, Lucifer 2, Money 2, Money 3, Money 4 & Money 5.
- Group III – Money 1 & Lucifer 3

Lucifer 6 separated from all other sites at 0% similarity level, as did Group III from Groups I & II. Group I separated from Group II at 24.3% similarity level. Overall Group I had 100% similarity, Group II had 67.3% similarity and Group III had 56.6% similarity.

3.2.2 Sediment Results

Results from Particle Size Analysis on the sediments from the Money-Weights and Lucifer Banks are presented in Table VIII.

	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt/ Clay	Classification
Money 1	0.00%	0.00%	0.16%	0.25%	10.92%	86.53%	0.21%	Very Well Sorted Fine Sand
Money 2	0.00%	0.00%	0.00%	0.06%	22.24%	76.19%	0.24%	Well Sorted Fine Sand
Money 3	0.00%	0.00%	0.00%	0.16%	5.30%	90.02%	3.00%	Very Well Sorted Fine Sand
Money 4	0.00%	0.00%	0.00%	0.00%	14.89%	83.02%	0.34%	Very Well Sorted Fine Sand
Money 5	0.00%	0.00%	0.00%	0.00%	3.62%	92.18%	2.57%	Very Well Sorted Fine Sand
Lucifer 1	0.00%	0.00%	0.00%	0.34%	23.87%	72.76%	1.24%	Well Sorted Fine Sand
Lucifer 2	0.00%	1.05%	0.20%	1.69%	72.46%	22.31%	0.19%	Slightly Very Fine Gravelly Medium Sand
Lucifer 3	0.00%	0.00%	0.00%	1.05%	49.47%	48.04%	0.40%	Moderately Well Sorted Medium Sand
Lucifer 4	0.00%	0.00%	0.00%	0.81%	80.79%	16.09%	0.15%	Well Sorted Medium Sand
Lucifer 5	0.00%	0.25%	0.50%	2.88%	80.30%	14.62%	0.23%	Slightly Very Fine Gravelly Medium Sand
Lucifer 6	0.00%	0.00%	0.09%	1.49%	82.83%	14.37%	0.12%	Well Sorted Medium Sand

Table VIII: Particle Size Analysis results for sediments taken along the Money-Weights and Lucifer Banks in April 2010.

Results from the particle size analysis indicates shows that the Money-Weights Bank is dominated by well sorted fine sands across the whole of the bank. All sites returned fine sand levels of between 76% and 92%. The highest silt clay content across both banks was present on the Money-Weights bank with Money 3 and Money 5 returning silt/clay figures of 3% and 2½% respectively. In contrast, 5 of the 6 sites across the Lucifer Bank were classified as medium sands. The exception, Lucifer 1, had 72.3% fine sands present. Silt/clay levels were low across the Lucifer Bank with values ranging from 0.12% at Lucifer 6 to 1.24% at Lucifer 1. The distribution of the sediment across both banks is presented in Figures 10 and 11.

Results from LOI analysis indicate very low organic values across the site (Table IX). LOI values across the bank ranged from 0.295% at Lucifer 1 to 0.675% at Money 5.

Station	Organic Carbon (% LOI)
Money 1	0.569
Money 2	0.503
Money 3	0.543
Money 4	0.550
Money 5	0.675
Lucifer 1	0.295
Lucifer 2	0.323
Lucifer 3	0.445
Lucifer 4	0.558
Lucifer 5	0.527
Lucifer 6	0.563

Table IX: Loss on Ignition results for sediments taken at the Money-Weights and Lucifer Banks in April 2010.

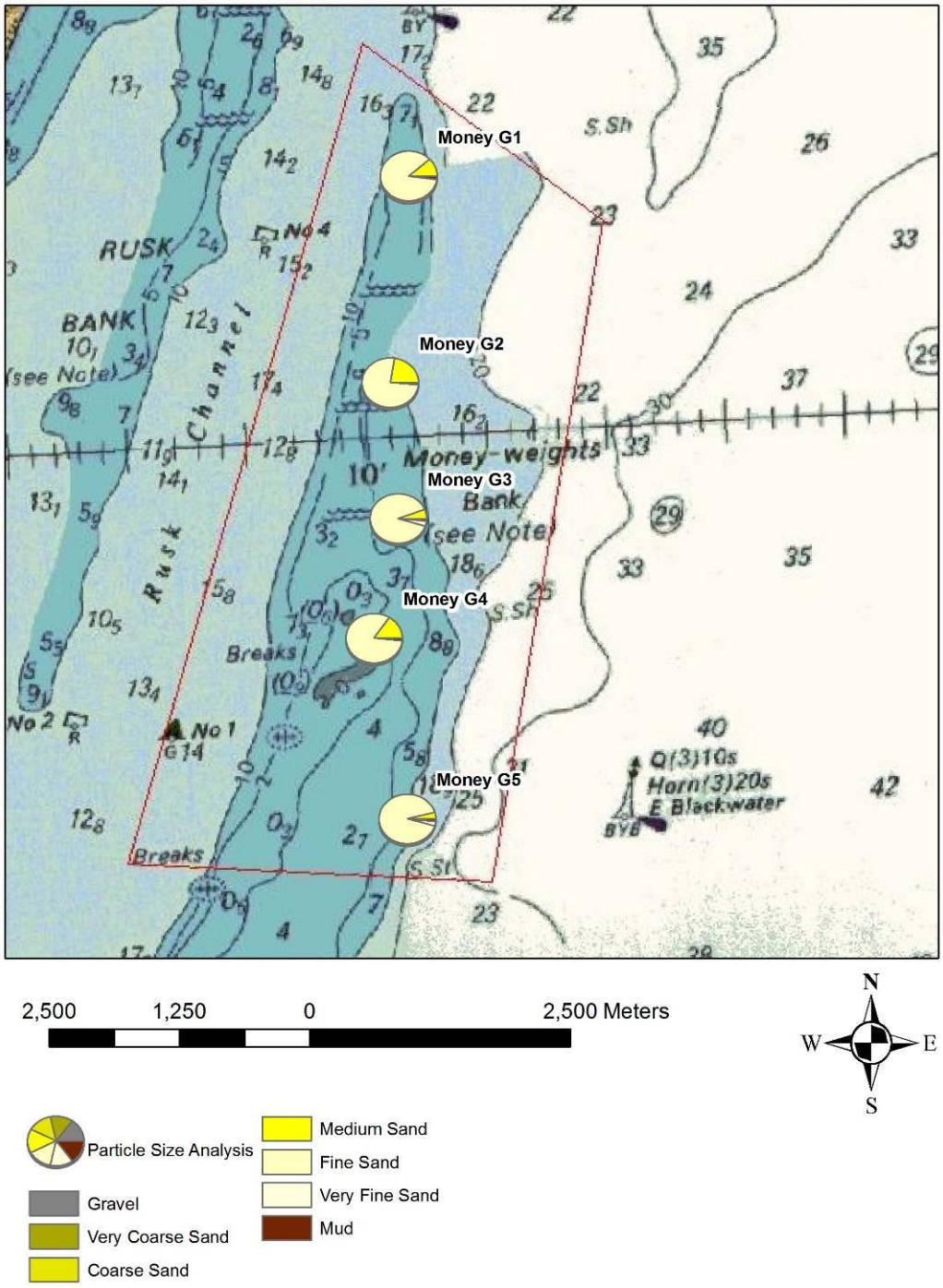

Figure 10: Sediment distribution across the Money-Weights Bank in April 2010. [Not to be used for Navigation © Crown Copyright and/or database rights. Reproduced under licence no. 14483 by permission of the Controller of Her Majesty's Stationery Office and the UK Hydrographic Office (www.ukho.gov.uk).]

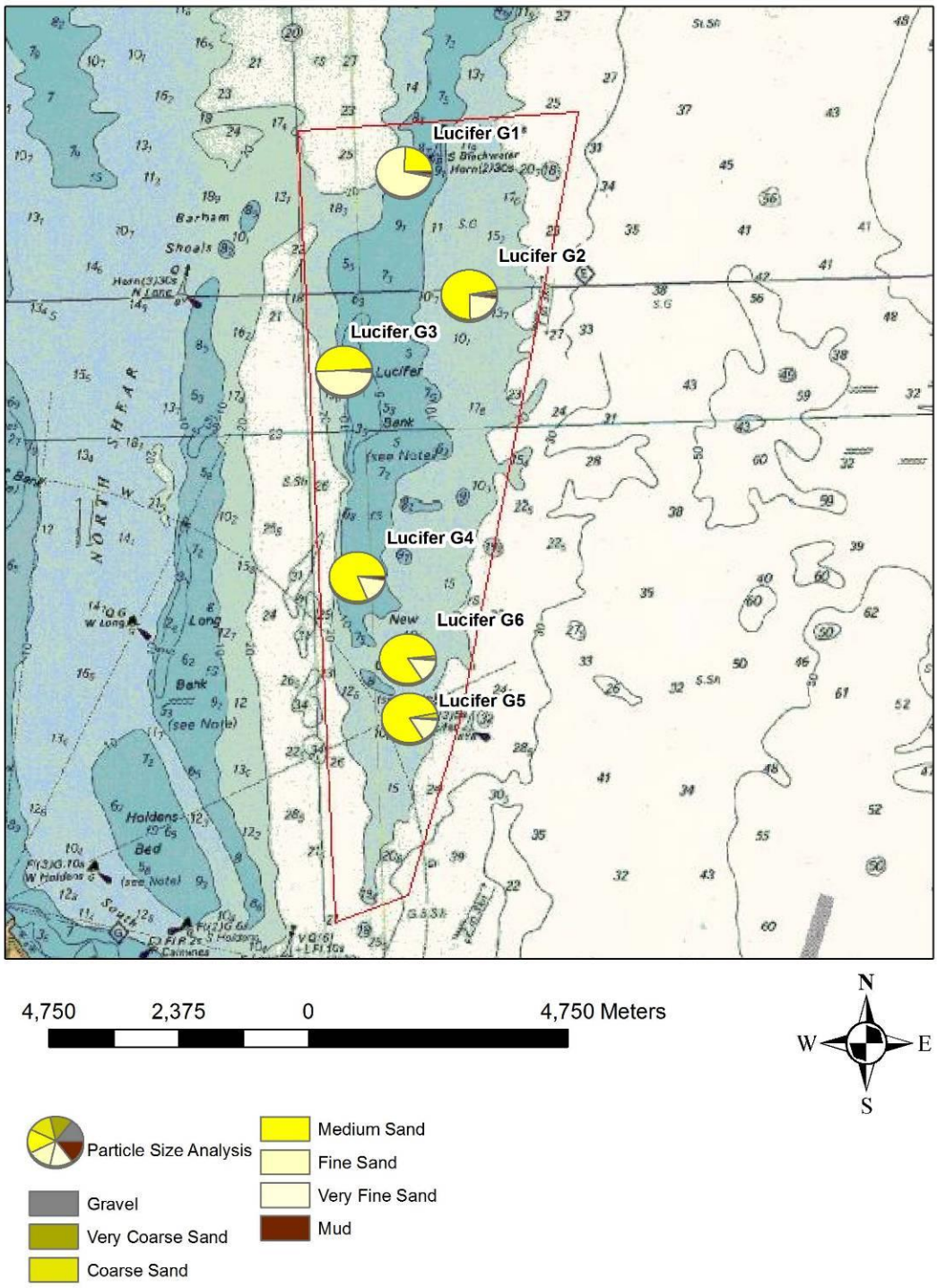

Figure 11: Sediment distribution across the Lucifer Bank in April 2010. [Not to be used for Navigation © Crown Copyright and/or database rights. Reproduced under licence no. 14483 by permission of the Controller of Her Majesty's Stationery Office and the UK Hydrographic Office (www.ukho.gov.uk).]

Figure 12 shows the PCA ordination of the sediment data analysed from the Money-Weights and Lucifer Banks. This two-dimensional ordination accounts for 70.0% of the overall variation. PC1 accounts for 49.8% of the variation and PC2 accounts for 20.2% of the variation. A clear

difference between both sandbanks is evident in the data, with all Money-Weights Bank stations grouped together as a result of the increased Fine Sand component of the sediment. This is highlighted by a black circle in Figure 12. Lucifer 1 separates from all Money-weight Bank sites as a result of the sedimentary

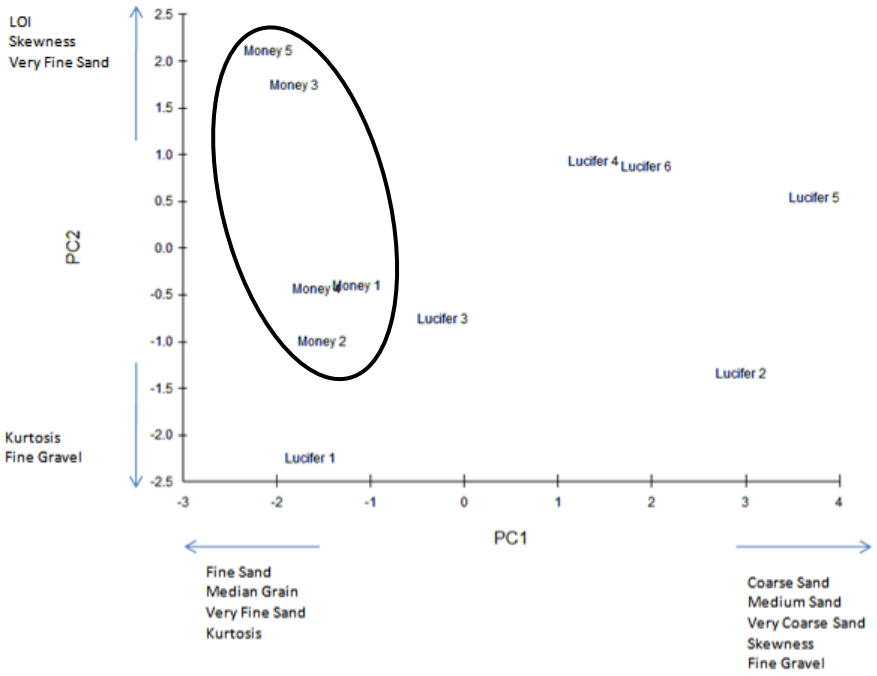

Figure 12: Two-dimensional PCA ordination of environmental data sampled at the Money-Weights and Lucifer Banks in April 2010.

3.2.3 Biotope Assessment

Multivariate analysis identified the presence of three distinct groups and a single outlier (Lucifer 6) across the two banks. Group I contained only a single species; the polychaete *Nephtys* cirrosa. This group has been classified as the biotope SS.SSa.IFiSa.IMoSa – Infralittoral mobile clean sand with sparse fauna.

Group II contained 4 species, the crustacean *Bathyporeia guillimasoniana* and the polychaetes *Glycera tridactyla, Nephtys cirrosa* & *Spio armata*. The crustacean *B. guillimasoniana* was present in all sites across Group II in abundances ranging from 1 in each of the Lucifer Bank sites to 11 at one site on the Money-Weights Bank (Money 5). This group has also been identified as the biotope SS.SSa.IFiSa.IMoSa – Infralittoral mobile clean sand with sparse fauna.

Group III contained 5 species, the fish *Ammodytes tobianus*, the crustaceans *Urothoe marina* and the polychaetes *Nephtys longosetosa, Schistomeringus* indet. & *Ophelia borealis*. As with all groups identified along the Money-Weights and Lucifer Banks, abundances and diversity values

are very low and as a result the group has been identified as the biotope SS.SSa.IFiSa.IMoSa – Infralittoral mobile clean sand with sparse fauna.

The single biotope identified is typical of medium to fine sandy sediment in shallow waters, such as those identified here. These sediments contain very little infauna due to the mobility of the sediments, with only opportunistic species likely to occur in low numbers such as *Bathyporeia guillimasoniana*, *Eurydice pulchra* and *Nephtys cirrosa*.

4 Discussion

It is important to note that these results be interpreted with caution as the low number of taxa encountered, in addition to the very low abundances may affect the accuracy of the analysis. However, general observations may be made on the data using the existing faunal and particle size data obtained.

Bray Bank

Faunal and sediment results for the Bray Bank indicate a highly dynamic environment across the full bank. Species diversity and abundances were suppressed at each site, reflecting the stressed nature of the communities present. Only a single biotope was identified on Bray Bank '*Infralittoral mobile clean sand with sparse fauna*'. All species identified in the present survey are typical for this type of hydrodynamic environment. This is also reflected in the sediment present on Bray Bank. The sediment ranged from medium to fine sands, with very low silt/clay and organic levels.

Money-Weight Bank & Lucifer Bank

The fauna present on the Money-Weights and Lucifer Banks are similar to those identified for the Bray Bank. Abundances and diversity indices were low across the banks, and fauna identified are typical of exposed, mobile sandy environments. Only a single biotope was identified in the present survey, '*Infralittoral mobile sand with sparse fauna*'. This is reflected in the sediment data for the area, with the Money-Weights Bank dominated by medium sands and the Lucifer Bank dominated by fine sands. Low organics and silt/clay values reflect the dynamic nature of the area.

Biotope Description

This biotope has been described (Connor *et al.*, 2004) as consisting of '*medium to fine sandy sediment in shallow water, often formed into dunes, on exposed or tide-swept coasts often contains very little infauna due to the mobility of the substratum. Some opportunistic populations of infaunal amphipods may occur, particularly in less mobile examples in conjunction with low numbers of mysids such as* Gastrosaccus spinifer, *the polychaete* Nephtys cirrosa *and the isopod* Eurydice pulchra. *Sand eels* Ammodytes *sp. may occasionally be observed in association with this biotope (and others). This biotope is more mobile than SSA.NcirBat and may be closely related to LSa.BarSa on the shore. Common epifaunal species*

such as Pagurus bernhardus, Liocarcinus depurator, Carcinus maenas *and* Asterias rubens *may be encountered and are the most conspicuous species present.*'

5 Conclusion

The abundances and diversity encountered in the Bray Bank, Money-Weights Bank and Lucifer Bank indicate each area is subjected to the influence of strong hydrodynamic factors across the full area of each bank. This is reflected in the sediment identified at all stations with the benthos characterised as medium to fine sands with low organics and silt/clay levels. Fauna typical of this environment were identified in the grabs, with the highly mobile polychaetes such as *Nephtys cirrosa* and *Nephtys longosetosa* and crustaceans such as *Bathyporeia guillimasoniana* and *Urothoe marina* identified across the banks in very low numbers.

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7 Appendices

7.1 Appendix 1: Photographic Plates

Plate 1: Sediment collected from Lucifer G1.

Plate 2: Sediment collected from Lucifer G2

Plate 3: Sediment collected from Lucifer G3

Plate 4: Sediment collected from Lucifer G4

Plate 5: Sediment collected from Lucifer G5

Plate 6: Sediment collected from Lucifer G6

Plate 7: Sediment collected from Money-Weights G1

Plate 8: Sediment collected from Money-Weights G2

Plate 8: Sediment collected from Money-Weights G3

Plate 9: Sediment collected from Money-Weights G4

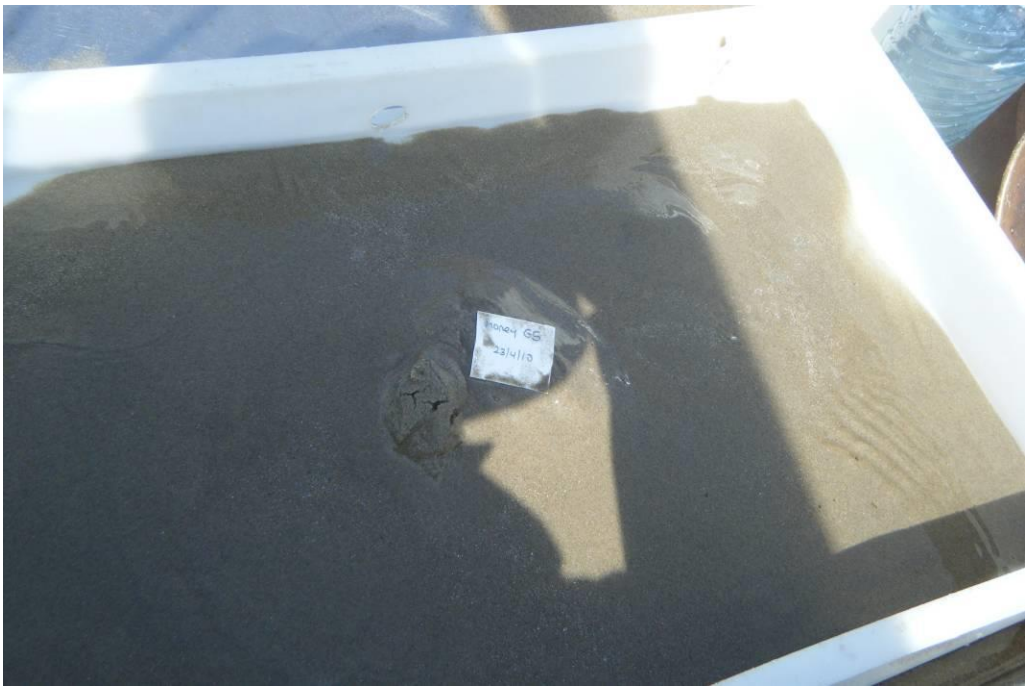

Plate 10: Sediment collected from Money-Weights G5

Plate 11: Sediment collected from Bray G1

Plate 12: Sediment collected from Bray G2

Plate 13: Sediment collected from Bray G3

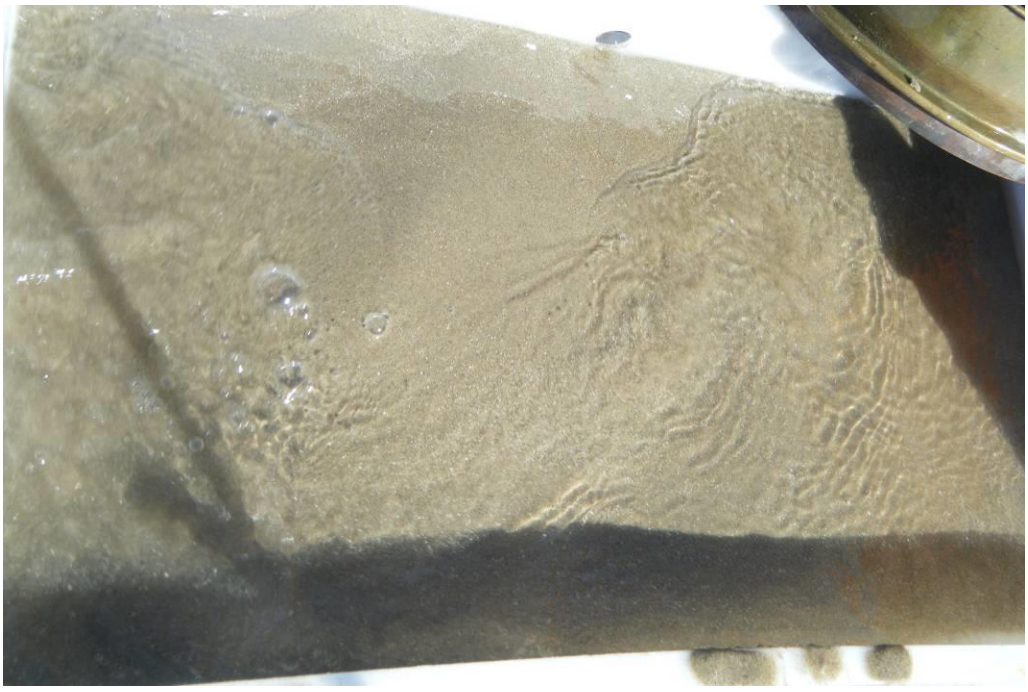

Plate 14: Sediment collected from Bray G4

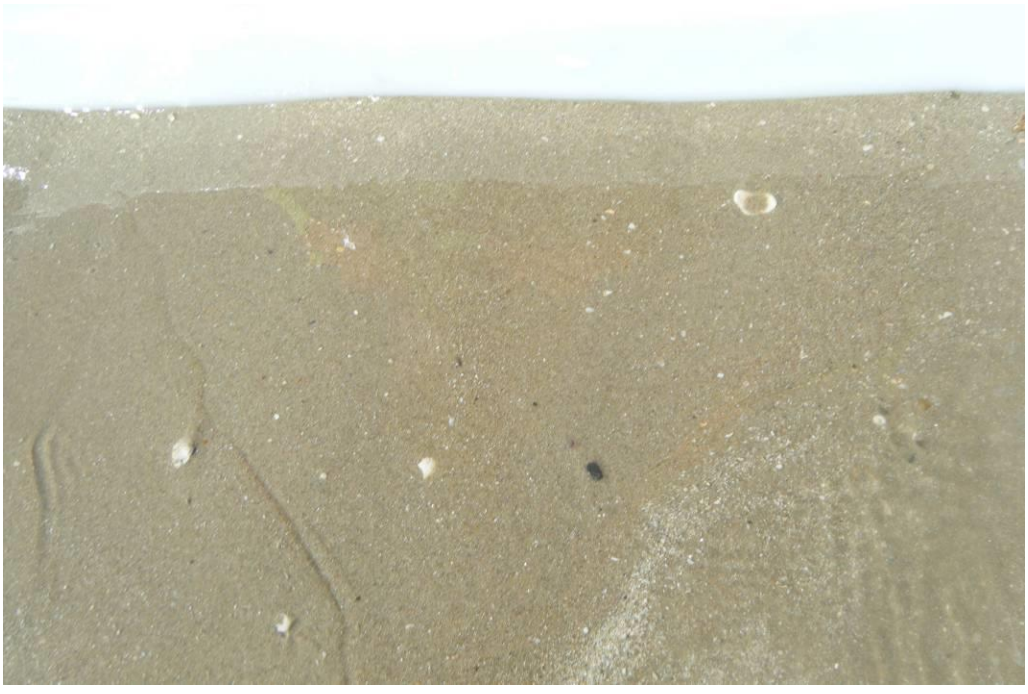

Plate 15: Sediment collected from Bray G5

Plate 16: Sediment collected from Bray G8

Plate 17: Sediment collected from Bray G9

Plate 18: Sediment collected from Bray G10

Plate 19: Sediment collected from Bray G11

Plate 20: Van-Veen grab ready for deployment over the Bray Bank in May 2010.

Plate 21: On-board sieving facilities aboard the MV Island Flyer, May 2010.

7.2 Appendix 2: Particle Size Results

	Lucifer G1	Lucifer G2	Lucifer G3	Lucifer G4	Lucifer G5	Lucifer G6
SAMPLE TYPE:	Unimodal, Well Sorted	Unimodal, Well Sorted	Bimodal, Moderately Well Sorted	Unimodal, Well Sorted	Unimodal, Well Sorted	Unimodal, Well Sorted
TEXTURAL GROUP:	Sand	Slightly Gravelly Sand	Sand	Sand	Slightly Gravelly Sand	Sand
SEDIMENT NAME:	Well Sorted Fine Sand	Slightly Very Fine Gravelly Medium Sand	Moderately Well Sorted Medium Sand	Well Sorted Medium Sand	Slightly Very Fine Gravelly Medium Sand	Well Sorted Medium Sand
MEAN (mm)	226.2	319.6	270.8	342.0	352.6	352.3
SORTING (mm)	1.350	1.388	1.420	1.363	1.353	1.341
SKEWNESS (mm)	0.183	-0.185	0.229	-0.398	-0.392	-0.397
KURTOSIS (mm)	1.674	0.795	0.802	0.874	0.925	0.921
MEAN (phi)	2.144	1.646	1.885	1.548	1.504	1.505
SORTING (phi)	0.433	0.473	0.505	0.446	0.436	0.423
SKEWNESS (phi)	-0.183	0.185	-0.229	0.398	0.392	0.397
KURTOSIS (phi)	1.674	0.795	0.802	0.874	0.925	0.921
% GRAVEL:	0.0%	1.1%	0.0%	0.0%	0.3%	0.0%
% SAND:	98.2%	96.9%	99.0%	97.8%	98.5%	98.9%
% MUD:	1.8%	2.1%	1.0%	2.2%	1.2%	1.1%
% V COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% MEDIUM GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% FINE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% V FINE GRAVEL:	0.0%	1.1%	0.0%	0.0%	0.3%	0.0%
% V COARSE SAND:	0.0%	0.2%	0.0%	0.0%	0.5%	0.1%
% COARSE SAND:	0.3%	1.7%	1.1%	0.8%	2.9%	1.5%
% MEDIUM SAND:	23.9%	72.5%	49.5%	80.8%	80.3%	82.8%
% FINE SAND:	72.8%	22.3%	48.0%	16.1%	14.6%	14.4%
% V FINE SAND:	1.2%	0.2%	0.4%	0.2%	0.2%	0.1%

	Money G1	Money G2	Money G3	Money G4	Money G5
SAMPLE TYPE:	Unimodal, Very Well Sorted	Unimodal, Well Sorted	Unimodal, Very Well Sorted	Unimodal, Very Well Sorted	Unimodal, Very Well Sorted
TEXTURAL GROUP:	Sand	Sand	Sand	Sand	Sand
SEDIMENT NAME:	Very Well Sorted Fine Sand	Well Sorted Fine Sand	Very Well Sorted Fine Sand	Very Well Sorted Fine Sand	Very Well Sorted Fine Sand
MEAN (mm)	211.0	224.1	186.8	211.0	178.9
SORTING (mm)	1.222	1.275	1.265	1.241	1.259
SKEWNESS (mm)	-0.024	0.120	-0.221	-0.019	-0.078
KURTOSIS (mm)	1.549	1.473	0.845	1.516	0.739
MEAN (phi)	2.245	2.158	2.421	2.244	2.483
SORTING (phi)	0.289	0.350	0.339	0.312	0.332
SKEWNESS (phi)	0.024	-0.120	0.221	0.019	0.078
KURTOSIS (phi)	1.549	1.473	0.845	1.516	0.739
% GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% SAND:	98.1%	98.7%	98.5%	98.3%	98.4%
% MUD:	1.9%	1.3%	1.5%	1.7%	1.6%
% V COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% MEDIUM GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% FINE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% V FINE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% V COARSE SAND:	0.2%	0.0%	0.0%	0.0%	0.0%
% COARSE SAND:	0.3%	0.1%	0.2%	0.0%	0.0%
% MEDIUM SAND:	10.9%	22.2%	5.3%	14.9%	3.6%
% FINE SAND:	86.5%	76.2%	90.0%	83.0%	92.2%
% V FINE SAND:	0.2%	0.2%	3.0%	0.3%	2.6%

	Bray G1	Bray G2	Bray G3	Bray G4	Bray G5	Bray G6
SAMPLE TYPE:	Unimodal, Poorly Sorted	Bimodal, Moderately Sorted	Unimodal, Well Sorted	Unimodal, Very Well Sorted	Bimodal, Moderately Sorted	Unimodal, Well Sorted
TEXTURAL GROUP:	Muddy Sand	Slightly Gravelly Sand	Sand	Sand	Slightly Gravelly Sand	Sand
SEDIMENT NAME:	Very Coarse Silty Medium Sand	Slightly Very Fine Gravelly Fine Sand	Well Sorted Fine Sand	Very Well Sorted Fine Sand	Slightly Very Fine Gravelly Fine Sand	Well Sorted Fine Sand
MEAN (mm)	98.26	258.5	183.6	200.3	275.6	228.3
SORTING (mm)	3.983	1.782	1.401	1.262	1.786	1.318
SKEWNESS (mm)	-0.760	0.327	0.045	-0.107	0.413	0.164
KURTOSIS (mm)	0.744	1.030	1.247	1.433	1.219	1.649
MEAN (phi)	3.347	1.952	2.446	2.320	1.860	2.131
SORTING (phi)	1.994	0.833	0.487	0.336	0.836	0.399
SKEWNESS (phi)	0.760	-0.327	-0.045	0.107	-0.413	-0.164
KURTOSIS (phi)	0.744	1.030	1.247	1.433	1.219	1.649
% GRAVEL:	0.0%	2.9%	0.0%	0.0%	2.8%	0.0%
% SAND:	66.0%	94.7%	97.4%	99.1%	96.3%	97.1%
% MUD:	34.0%	2.3%	2.6%	0.9%	0.9%	2.9%
% V COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% MEDIUM GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% FINE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% V FINE GRAVEL:	0.0%	2.9%	0.0%	0.0%	2.8%	0.0%
% V COARSE SAND:	0.0%	1.8%	0.4%	0.0%	3.2%	0.2%
% COARSE SAND:	1.3%	6.8%	1.0%	0.3%	6.6%	1.1%
% MEDIUM SAND:	36.6%	32.5%	10.8%	9.8%	35.5%	23.6%
% FINE SAND:	27.9%	52.5%	81.4%	88.6%	50.5%	72.1%
% V FINE SAND:	0.2%	1.0%	3.8%	0.4%	0.4%	0.2%

	Bray G7	Bray G8	Bray G9	Bray G10	Bray G11
SAMPLE TYPE:	Unimodal, Very Well Sorted	Unimodal, Well Sorted	Unimodal, Very Well Sorted	Unimodal, Very Well Sorted	Unimodal, Well Sorted
TEXTURAL GROUP:	Slightly Gravelly Sand	Sand	Sand	Sand	Sand
SEDIMENT NAME:	Slightly Very Fine Gravelly Fine Sand	Well Sorted Medium Sand	Very Well Sorted Medium Sand	Very Well Sorted Medium Sand	Well Sorted Medium Sand
MEAN (mm)	217.2	280.4	412.7	429.4	354.8
SORTING (mm)	1.256	1.398	1.233	1.255	1.330
SKEWNESS (mm)	0.084	0.175	-0.210	0.003	-0.365
KURTOSIS (mm)	1.574	0.836	1.667	1.538	0.936
MEAN (phi)	2.203	1.835	1.277	1.220	1.495
SORTING (phi)	0.329	0.483	0.302	0.327	0.411
SKEWNESS (phi)	-0.084	-0.175	0.210	-0.003	0.365
KURTOSIS (phi)	1.574	0.836	1.667	1.538	0.936
% GRAVEL:	0.4%	0.0%	0.0%	0.0%	0.0%
% SAND:	98.7%	98.4%	98.3%	98.3%	98.0%
% MUD:	0.9%	1.6%	1.7%	1.7%	2.0%
% V COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% COARSE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% MEDIUM GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% FINE GRAVEL:	0.0%	0.0%	0.0%	0.0%	0.0%
% V FINE GRAVEL:	0.4%	0.0%	0.0%	0.0%	0.0%
% V COARSE SAND:	0.3%	0.3%	0.0%	0.0%	0.0%
% COARSE SAND:	0.2%	4.3%	6.1%	17.3%	1.9%
% MEDIUM SAND:	16.9%	52.8%	86.7%	79.0%	84.5%
% FINE SAND:	80.9%	40.9%	5.5%	2.0%	11.5%
% V FINE SAND:	0.5%	0.1%	0.0%	0.0%	0.1%

7.3 Appendix 3: Ships Log

Date: 23/04/2010
Personnel: [redacted].
Vessel: MV Island Flyer
Sea State: Good visibility, calm seas (F2)
Sampler Used: 0.1m^2 Stainless Steel Van-Veen Grab – All Sites

Sample ID	Date	Time	Easting UTM (29N)	Northing UTM (29N)	Depth (under vessel)	Photo	Ship Anchored	Desc of Sample	Sieve Size	Depth of Sample (cm)
Lucifer G5	23/04/2010	10:40	689372	5796492	15m	Yes	N	Coarse Sand – No redox	1.0mm	8cm
Lucifer G6	23/04/2010	10:35	689338	5797490	16m	Yes	N	Sand	1.0mm	7cm
Lucifer G4	23/04/2010	10:50	688414	5798993	9m	Yes	N	Sand – No redox	1.0mm	7cm
Lucifer G3	23/04/2010	11:05	688171	5802764	9m	Yes	N	Sand – No Redox	1.0mm	8cm
Lucifer G2	23/04/2010	11:20	690467	5804154	15m	Yes	N	Sand – No Redox	1.0mm	8cm
Lucifer G1	23/04/2010	11:30	689326	5806420	11m	No	N	No Sample	-	No sample
Lucifer G1	23/04/2010	11:35	689271	5806405	11m	Yes	N	Sand	1.0mm	8cm
Money G5	23/04/2010	11:55	692636	5816762	2.9m	No	N	No Sample	-	No Sample
Money G5	23/04/2010	12:05	692647	5816799	2.5m	Yes	N	Good Sample	1.0mm	8cm
Money G4	23/04/2010	12:15	692300	5818514	2.9m	No	N	No Sample	-	No Sample
Money G4	23/04/2010	12:20	692327	5818535	2.9m	Yes	N	Good sample – sand	1.0mm	8cm
Money G3	23/04/2010	12:30	692560	5819684	10.3m	No	N	No Sample	-	No Sample

Sample ID	Date	Time	Easting UTM (29N)	Northing UTM (29N)	Depth (under vessel)	Photo	Ship Anchored	Desc of Sample	Sieve Size	Depth of Sample (cm)
Money G3	23/04/2010	12:35	692560	5819684	10.5m	Yes	N	Sand – good sample	1.0mm	7cm
Money G2	23/04/2010	12:40	693430	5820452	18.2m	No	N	Hard Benthos	-	No Sample
Money G2	23/04/2010	12:45	692781	5820894	16.3m	No	N	Hard Benthos – moved WNW from original position	-	No Sample
Money G2	23/04/2010	12:55	692483	5820990	5.7m	Yes	N	Good sample – sand. Moved W from previous position	1.0mm	9cm
Money G1	23/04/2010	13:05	692659	5822972	6.3m	Yes	N	Good Sample – Sand	1.0mm	10cm

Sampling completed for 23/04/2010 due to weather deteriorating on the Bray Bank. Winds freshened from the south and increased to F5 very quickly. Sampling on the Bray Bank wasn't possible due to the swinging action on the winch & davit. Decision made to head back to port on consultation with the vessels skipper.

Date: 28/05/2010
Personnel: [redacted].
Vessel: MV Island Flyer
Sea State: Good visibility, relatively calm seas (F3)
Sampler Used: 0.1m^2 Stainless Steel Van-Veen Grab – All Sites

Sample ID	Date	Time	Easting UTM (29N)	Northing UTM (29N)	Depth (under vessel)	Photo	Ship Anchored	Desc of Sample	Sieve Size	Depth of Sample (cm)
Bray G1	28/05/2010	08:50	706600	5902783	8.5m	Yes	N	Med-Fine Sand Good Sample	1.0mm	8cm
Bray G3	28/05/2010	09:05	706830	5900980	24m	Yes	N	Grey Sand	1.0mm	6cm
Bray G2	28/05/2010	09:20	706188	5901023	11m	Yes	N	Sand	1.0mm	5cm
Bray G4	28/05/2010	09:42	706307	5899632	6m	Yes	N	Sand	1.0mm	8cm
Bray G5	28/05/2010	09:55	705794	5898743	18m	Yes	N	Sand	1.0mm	8cm
Bray G6	28/05/2010	10:05	706274	5897837	6m	No	N	Sand	1.0mm	7cm
Bray G7	28/05/2010	10:15	706374	5897676	16.5m	No	N	Sand	1.0mm	7cm
Bray G8	28/05/2010	10:30	706552	5896124	8m	Yes	N	Shelly Sand – Good Sample	1.0mm	10cm
Bray G9	28/05/2010	10:35	706396	5894850	15m	Yes	N	Good sample – coarse sand	1.0mm	10cm
Bray G11	28/05/2010	10:50	706764	5896545	13.5m	Yes	N	Good sample – coarse sand	1.0mm	12cm
Bray G10	28/05/2010	11:05	706923	5894495	6m	Yes	N	Good sample – coarse sand	1.0mm	14cm